

Atlantic Hurricanes and Climate Change – Results from Regional Model Downscaling

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Results of recent statistical analyses comparing Atlantic hurricane activity to the secular rise in tropical Atlantic sea surface temperatures (SSTs) since 1950 (Emanuel, 2007) have raised concern that future global warming could produce a very strong increase in Atlantic basin hurricane activity. To address this concern, we have undertaken a regional downscaling study, focusing on the Atlantic basin.

Our strategy was first to demonstrate that our regional downscaling model is a useful tool for the study of Atlantic hurricane activity. To do this, we performed a “proof of concept” experiment (Knutson et al. 2007), in which we supplied (via interior spectral nudging) only the large-scale time-evolving atmospheric fields (domain wavenumbers 0-2) to a regional model of the Atlantic basin, and then allowed the model to develop tropical storms and hurricanes based on those conditions (Fig. 1). A 27-season sample using this approach demonstrates that the regional model can indeed recover substantial information about hurricane counts (Fig. 2), with a year-to-year variability correlation (model vs observed) of 0.84.

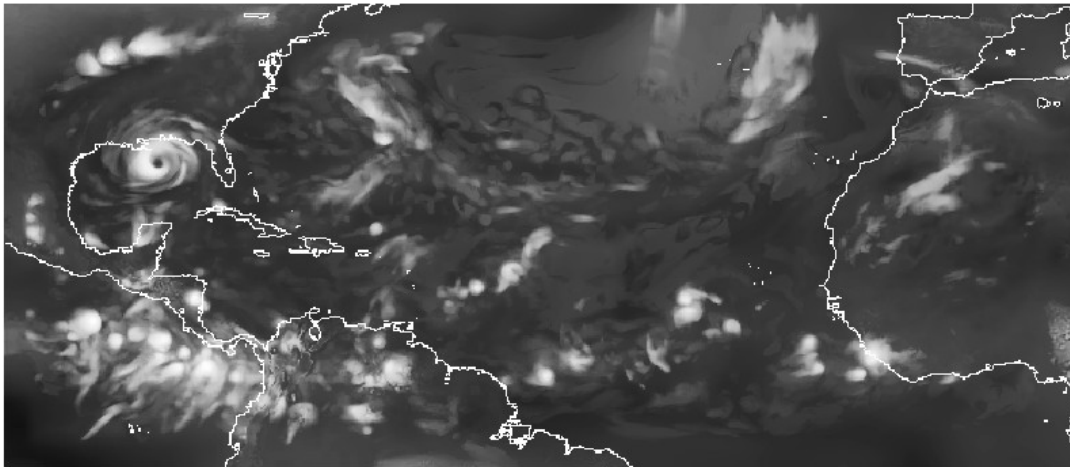


Fig. 1. Snapshot of model outgoing longwave radiation (W m^{-2}) illustrating scales of disturbances in the regional model. A model-generated hurricane is seen approaching the U.S. Gulf Coast for the 2005 season simulation.

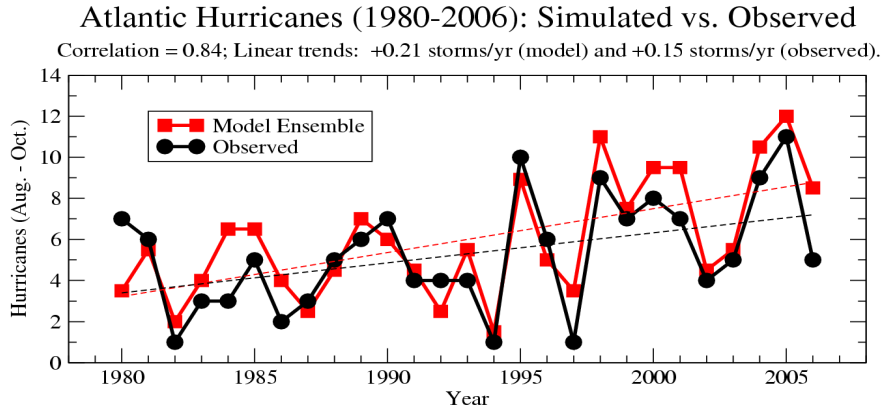


Fig. 2. Annual number (Aug.-Oct. of simulated and observed Atlantic basin hurricanes for the years 1980-2006, based on downscaling of NCEP Reanalyses into a regional climate model.

Having established that the regional model simulates a credible base level and interannual variability of hurricanes when supplied with “perfect” large-scale conditions, we then re-ran those 27 seasons, but modifying the “perfect” atmospheric conditions according the climate change simulated for the late 21st century (IPCC A1B scenario) by an ensemble of 18 CMIP3 climate models (Knutson et al. 2008). In this experiment, the number of tropical storms and hurricanes was reduced compared to the control runs (Fig. 3), as enhanced vertical shear and other environmental changes dominate over the increases in SST and related tropical cyclone potential intensity.

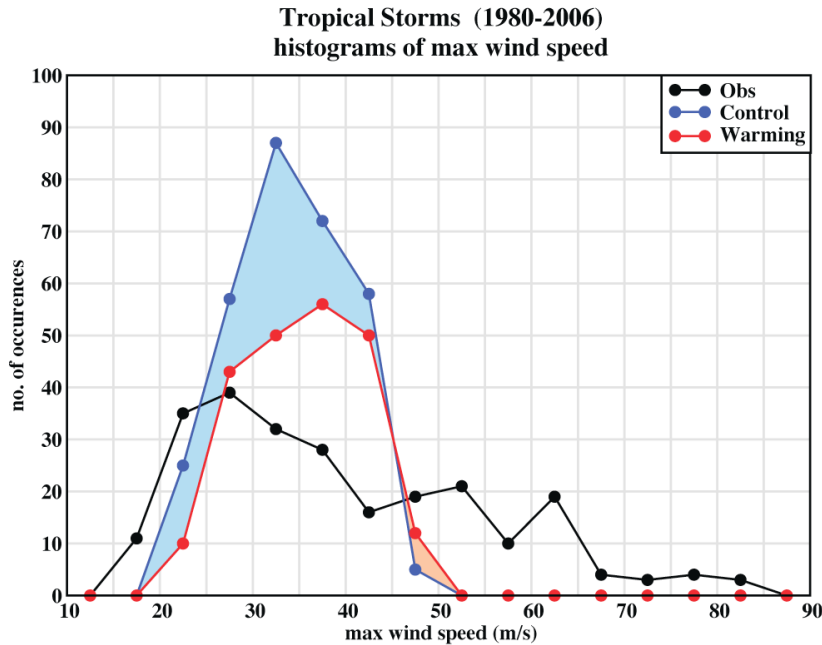


Fig. 3. Distribution of maximum surface wind speeds of tropical cyclones simulated for the years 1980-2006 (control) using NCEP Reanalysis forcing, or simulated for a warmed climate version of these conditions. See Knutson et al. 2008 for details.

The initial sets of climate change experiments with the regional downscaling climate model and the hurricane prediction model used an 18-model ensemble mean climate change as the projection of late 21-century conditions. Further tests are being conducted using climate change conditions from several individual climate models that make up the 18-model ensemble (Fig. 4), in order to illustrate the range of Atlantic hurricane activity responses implied by the range of climate model projections.

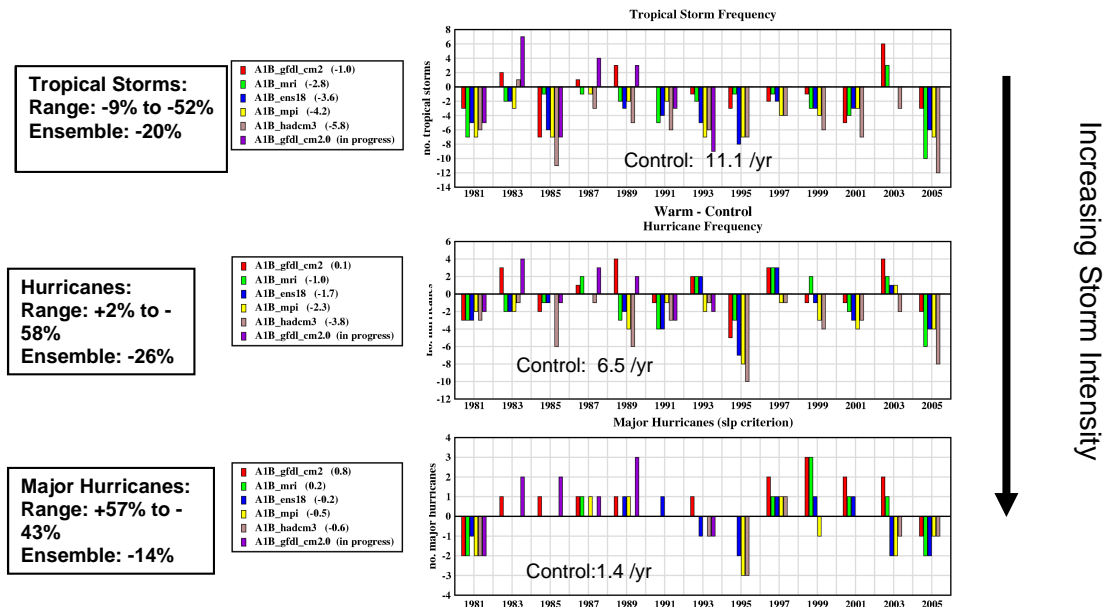


Fig. 4. Tropical storm, hurricane, and major hurricane count changes between control and warm climate experiments with the GFDL Zetac regional model. Colors represent different global climate model projections used for the downscaling experiments. Results shown for individual seasons simulated.

The regional modeling experiments just described used a model with horizontal grid spacing of 18km, a choice which was dictated by available computing resources, as these experiments required approximately 1.5 Million CPU hours to perform. However, even with this large computational expense, the model failed to simulate the most intense (and most damaging) hurricanes: the maximum simulated wind speeds were only about 47 m/s (Fig. 3). To address this shortcoming, we performed an additional downscaling step, in which each individual storm case from the 27 seasons using the regional model was further downscaled into a 5-day run of the GFDL hurricane prediction system. That operational system, with a triply nested moveable mesh and horizontal grid spacing as fine as 9km--and including ocean coupling--does simulate the more intense hurricanes

reaching categories 3 and 4. Results from the model under warm climate conditions will be reported on at the meeting.

References:

- Emanuel, K., 2007a: Environmental factors affecting tropical cyclone power dissipation. *J. Climate*, **20**, 5497–5509.
- Knutson, T. R., J. J. Sirutis, S. T. Garner, I. M. Held, and R. E. Tuleya, 2007: Simulation of the recent multidecadal increase of Atlantic Hurricane activity using an 18-km-Grid Regional Model. *Bull. Amer. Meteor. Soc.*, **88**(10), 1549-1565.
- Knutson, T. R., J. J. Sirutis, S. T. Garner, G. A. Vecchi, and I. M. Held, 2008 : Simulated reduction in Atlantic hurricane frequency under 21st century warming conditions. *Nature Geoscience*, **1**, 359-364.